



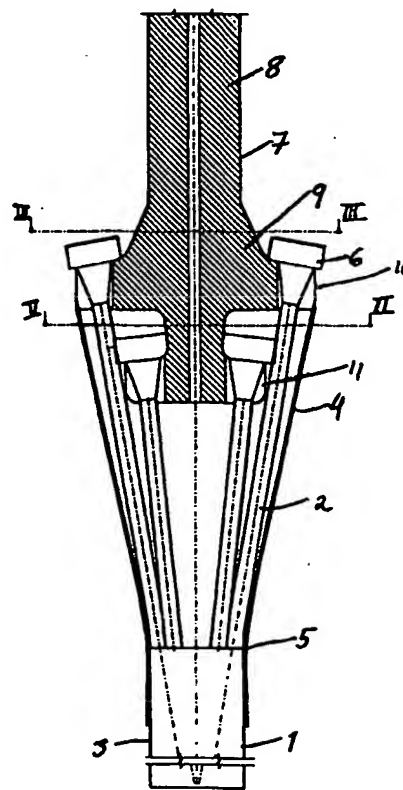
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(54) Title: TERMINATION OF A TENSION MEMBER, FOR USE AS A TENDON FOR A TENSION LEG PLATFORM

(57) Abstract

A termination of a tension member (1), for use as a tendon or tether for a tension leg platform. The tension member (1) consists of a plurality of carbon fibre filaments gathered into one or more strands (2) in which the filaments run against one another. A sheath (3) is provided around the strands. Each strand (2) is terminated in a receiving member (6) and the receiving member (6) is suspended in a recess (12) in a suspension member (7). The strands (1) are, over an area, spread out from a bundled strand to an arrangement of the individual filaments lying apart from each other. This spread-out area is held together by a protective cone (10) which prevents the spreading out from travelling down the strand. The individual carbon fibre filaments (2) are inserted into respective cavities (4) in a receiving member (3) and secured therein with a solidifying substance (5). The cavities in the receiving body (3) may be through-going, or they may be blind. Moreover, the cavities (4) may be of different configurations, from a hole of uniform diameter, an upward or downward facing conical cavity, or a gradually stepped cavity. By securing the carbon fibre filaments in this way, a good anchoring of each individual filament is ensured, as well as a longitudinal adjustment of the filaments, which gives a uniformly distributed load over the strand (1), and that in the main only axial forces are applied to the individual carbon fibre filaments (2).



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**TERMINATION OF A TENSION MEMBER,
FOR USE AS A TENDON FOR A TENSION LEG PLATFORM**

The present invention relates to a termination of a tension member in accordance with
5 the preamble of claims 1, 11 or 15.

The tension member of the invention is intended primarily to be used in connection with
tendons or tethers for tension leg platforms, but other applications are also possible,
such as stays or wires for bridges, (e.g., suspension bridges or cable-stayed bridges), the
10 bracing of tunnels or other applications where there is a need for a lightweight, strong
wire or stay. The invention is therefore not limited to the application described below.

Tension leg platforms are widely used in drilling and production on oil fields where for
various reasons it is not possible or financially viable to install a fixed platform, and
15 where it would not be expedient to use a floating platform moored by means of anchors
and anchor chains.

Tension leg platforms are in principle floating platforms, where, however, instead of a
slack mooring by means of anchors and anchor chains, tendons extend from the
20 platform approximately vertically down to an anchorage on the seafloor. The tendons
are put under considerable tension to ensure that the platform stays as much as possible
in the same position relative to the seafloor. The stable position of the platform is of
great advantage for both drilling and production. However, this makes heavy demands
on the tendons used, their attachment to the platform and the anchorage on the seafloor.

25 Today's tendons consist of steel pipes in sections. The sections may be of different
lengths and different diameters and have different wall thicknesses. Insofar as strength
is concerned, it is an advantage for the steel pipes to have a large wall thickness, but as
regards weight and thus also the load on the attachment to the platform, it is an
30 advantage if the wall thickness is small. Wall thickness will therefore always be chosen
as a compromise between strength and weight. These steel tendons function well at
moderate depths, i.e., depths of a few hundred metres. However, oil and gas production
is now taking place at ever-greater depths, often up to 2000 m. Under such conditions
heavy demands are made on the strength of the tendons, and tendons of steel are not
35 usable. On account of the increased strength requirement, the wall thickness would
have to be very large and the pipes would thus be extremely heavy. To facilitate
transport, they would also have to consist of very many sections which would need to be

joined together during installation. The tendons would thus have a considerable number of joints, which would also add to the substantial increase in weight. To counteract this increase in weight it would therefore be necessary to equip the tendons with a large number of floats. All this would result in a very costly and heavy installation.

5

Carbon fibres, with their low weight and high tensile strength, have already been used in various areas in connection with oil and gas recovery, for example, as hoisting cable for great depths, where the weight of a hoisting cable in steel would create problems.

10 According to the present invention, one of the objects is to exploit the advantageous properties of the carbon fibres, in particular their great strength when subjected to tensile stress, also when used in tendons. However, carbon fibres also have one considerable negative property; they have very small breaking strength when subjected to shearing stress. When terminating a tendon consisting of carbon fibres, this will have
15 to be taken into account.

According to the present invention, one of the objects is to exploit the advantageous properties of the carbon fibres, or other fibres having similar properties, in particular their great strength when subjected to tensile stress, also when used in tendons.

20 However, carbon fibres also have one considerable negative property; they have very small breaking strength when subjected to shearing stress. When terminating a tendon consisting of carbon fibres, this will have to be taken into account.

Another object of the present invention is to provide a termination for tendon of
25 preferably carbon fibres, which can be used for tension leg platforms at great depths, where the carbon fibres are not subjected to shearing stress. However, other fibre materials having approximately the same properties as carbon fibres may also be used, for example, glass fibres.

30 Yet another object of the present invention is to provide a termination of strands in a tension member, which in turn forms a part of a tendon or tether of carbon fibres, which can be used for tension leg platforms at great depths, where the carbon fibres are not exposed to shearing stress, but only approximately axial forces.

35 US 5611636 shows a termination of a cable, where the filaments of the cable are fed into a receiving member. By virtue of an eye at the end of the receiving member, this can be coupled to a fixed point or other object.

US 4673309 shows a method for anchoring a cable in a receiving member. It is not shown how the receiving member is supposed to be coupled to a fixed point or an object.

5 US 4.454.633 describes a device for anchoring of a cable in a receiving member. As above, it is not shown how the receiving member is supposed to be coupled to a fixed point or an object.

10 GB 129579 describes a termination of a cable similar to the above cable of US 4454633. Here too the strands are anchored in a conical sleeve, which in its turn is anchored in a suspension member. The disadvantage of the conical sleeves is that a squeezing of the strands occur, which with regard to carbon fibre leads to shear forces on the filaments, which in its turn easily leads to fracture.

15 GB 1571327 shows a termination of a strand. Nor here it is shown how the receiving member is to be coupled to a fixed point or an object.

When using carbon fibres in a tension member for use as a tendon, the carbon fibres will
20 be present as filaments which together form bundles or strands, which in turn are arranged in a sheath so as form a tension member. This means that the individual filaments must be terminated for each strand. Traditionally this has been done in various ways, e.g., by inserting all the filaments into a cavity in a body and securing them therein mechanically, or, e.g., with a solidifying substance. The disadvantages of
25 this are that there is little or no control of the size of the load each individual filament takes up when the strand is loaded, since there is no control of their positioning relative to one another in the receiving member, whilst the securing of the filaments may result in individual filaments in e.g., a mechanical clamp termination, not being secured in a satisfactory manner which in turn may result in failure when load is applied.

30 From DE 2407828 it is known a termination where the filaments are anchored together in a binder material, which in addition is put under pressure. The filaments are indeed spread out in a fan like form with the aid of an anchoring plate, but the proper anchoring takes place in the binder material, which leads to different loading of each filament.

De 2700378 also shows a termination of filaments, where the filaments are anchored together in a binder material. As with the above reference, this will lead to different loading of the filaments.

- 5 Nor is there any control of the load distribution and local loading in the solidifying substance.

The termination of such tendons requires special measures, as the carbon filaments otherwise could easily break, the tendon thereby being considerably weakened, or at
10 worst collapsing completely. An expedient termination of such tension members is the object of the present invention, which is its basic embodiment is disclosed in the characterising clause in claims 11 or 15 below.

The termination of such tendons legs, and especially some elements such as the
15 individual fibres, requires special measures, as the carbon filaments otherwise could easily break, the tension leg thereby being considerably weakened, or at worst collapsing completely. Furthermore, uneven load distribution on the different carbon fibre filaments could occur and this in turn could result in undesirable high tension concentrations in single filaments or the solidifying substance.

20 An expedient termination of the carbon fibre elements in the strands in a tension members is the object of the present invention, which is its basic embodiment is disclosed in the characterising clause in claim 1 below.

- 25 The invention will now be described in more detail with reference to the accompanying drawings, wherein:

Figure 1 is a sectional view through a termination along the line I-I in Figure 3;

- 30 Figure 2 is a cross-sectional view through a termination along line II-II in Figure 2; and

Figure 3 is a sectional view through a termination along line III-III in Figure 1.

Figure 4 is a simplified view of the termination of a single strand in a tension member;

35

Figure 5 is a perspective view of the termination in Figure 1; and

Figures 6a-6d illustrate different embodiments of the termination of each individual carbon fibre filament in the strand.

5 Figure 1 shows a longitudinal section through the termination of a tension member 1, according to the invention. The tension member 1 consists of a plurality of bundles or strands 2, which each consist of a large number of carbon fibre filaments. A protective sheath 3 is provided around the strands 2. Over a section of the member close to the termination, the sheath is removed so that the strands 2 are fully exposed. The strands 2
10 are spread out over this section inside a protective cone 4. The protective cone 4 is brought against the tension member 1 at the end 5 of the sheath 3, so that the strands are held together here.

A receiving member 6 is attached to each strand. The receiving members are in turn
15 suspended in a suspension member 7. The suspension member 7 consists of a body 8 and a suspension part 9. In the illustrated example, the suspension part 9 consists of two shoulders, an upper shoulder 10 and a lower shoulder 11.

Figure 2 shows a section through the termination immediately the lower shoulder 11,
20 see downwards in Figure 1. Here, it can be seen that the lower shoulder 11 is generally circular, and is equipped with a plurality, in this case five, recesses 12. The recesses 12 have a maximum dimension that is less than the dimension of the receiving member 6, but greater than the dimension of the strand 2 close to the receiving member 6. In Figure 2, two receiving members 6 are shown each suspended in their respective recess
25 12. The strands 2 which extend beyond the lower shoulder 11 and up to the upper shoulder 10 are also shown.

Figure 3 shows a section through the termination immediately above the upper shoulder 10, seen downwards in Figure 1. The upper shoulder 10 is generally made in the same
30 way as the lower shoulder 11, but has a substantially greater diameter, so that the strands 2 which extend up towards the upper shoulder 10 can pass beyond the lower shoulder 11 without coming into contact therewith. Consequently, the shoulder 10 also has a greater number of recesses 12 than the shoulder 11.

35 The suspension member 7 does not need to consist of two shoulders, but may consist of as many shoulders as is practically possible to provide, so that this termination may also be used for much more substantial tension members. For less substantial tension

members it may be sufficient to equip the suspension member with one shoulder. The shoulders do not necessarily need to be circular, but may be of any suitable shape whatsoever.

- 5 Furthermore, the recesses 12 may have a seat adapted to the shape of the receiving member. In the illustrated exemplary embodiment the receiving member 6 is plate-shaped with a flat underside, but it may also be conical and accommodated in a conical seat in the recess 12.
- 10 As an alternative to shoulders for suspension of the receiving member, the recesses may be made in the form of steps which accommodate one or more recesses. The steps may be distributed across a longitudinal portion of the suspension member, either singly or in groups.
- 15 The suspension member 7 may in turn be secured respectively to the platform and/or to an anchorage on the seafloor, in a conventional manner.

Figure 4 shows in principle how a strand 1 is terminated according to the present invention. The strand 1 consists of filaments 2 which are each inserted into a cavity 4 in
20 a receiving member 3, and secured in the cavities using a solidifying substance 5. Each strand 1 is split up into its respective filaments 2 over an area of the strand 1 in proximity of the receiving member 3. The area where the strand 1 flares into the individual filaments 2 is surrounded by a protective cone 10 which in its lower part holds the strand 1 together, so that the spreading out of the individual filaments does not
25 travel further down the strand 1 from the transition area between the strand 1 and the individual filaments 2. The upper opening of the protective cone 10 is greater than the lower opening thereof and allows a spreading out of the filaments 2 in the direction of the receiving member 3 from the upper end of the protective cone 10.

- 30 The receiving member 3 is prepared for the termination of the strand 1 in that a plurality of cavities 4 are provided therein. These cavities may be through-going, as indicated in Fig. 5, or they may be blind. Furthermore, the cavities may be of different shapes, as indicated in Figs. 6a-6d. Fig. 6a shows an embodiment where the cavity 4 is a blind hole, the diameter of which is the same from the opening to the end. Here, the filament
35 2 has been inserted almost to the end, and is secured to the receiving member 3 in the cavity 4 by means of a solidifying substance 5. In the exemplary embodiment shown in Fig. 6b, the cavity 4 has been made by stepwise boring into the receiving member 3,

which at the opening gives a larger diameter than each of the three further indicated borings. Here too, the filaments 2 are inserted almost to the end of the cavity 4, and then secured to the receiving member 3 by filling the cavity 4 with a solidifying substance 5. In Fig. 6c the cavity 4 is shown having a lower conical portion where from
5 the opening of the cavity there is a conically tapering shape to some way inside the cavity 4, after which the cavity has a uniform diameter. In this case too, the filament 2 is inserted into the cavity almost to the end, whereupon the cavity 4 in the receiving member 3 is filled with a solidifying substance 5. In Fig. 6d the cavity 4 is indicated by a downward facing continuous conical form which at the entrance of the cavity 4 has a
10 diameter that is somewhat greater than the filament 2, whereafter the diameter of the cavity increases inwards to the end of the cavity. The filament 2 is inserted herein in this case too, whereupon the solidifying substance 5 is poured into the cavity 4.

The foregoing exemplary embodiments from Figs. 6a-6d are only to be regarded as
15 illustrations, whereupon it is possible to vary the shape of the cavity and the insertion within the scope given in the following set of claims. Moreover, in Figs. 6a-6d only blind cavities are illustrated, without this being considered to be limiting, as the different configurations of the cavities described herein may also apply if the cavities are through-going in the receiving member 3.

Patent claims

1.

A termination of bundles or strands in a tension member, which tension member
5 consists of a plurality of fibre filaments (2) gathered into one or more bundles or strands
(1), in which the filaments (2) run against one another, around which bundles or strands
(1) there is arranged a sheath or sleeve, characterised in that each filament (2) in each
bundle or strand is spread apart from the others in a transition zone and is inserted into
its respective hole (4) in a receiving member (3), and is fixed relative to the holes (4) by
10 a solidifying substance (5).

2.

A tension member termination according to Claim 1, characterised in that the receiving
member (3) is plate-shaped.

15

3.

A tension member termination according to Claim 2, characterised in that the receiving
member (3) is circular in shape.

20 4.

A tension member termination according to one of the preceding claims, characterised
in that the holes (4) in the receiving member (3) for receiving the filaments (2) have an
increasing diameter, e.g., conical or stepwise, where the filaments (2) are inserted into
the end of the hole (4) having the smallest diameter, and that the solidifying substance
25 (5) is poured into the hole (4) around the filament (2), and thereby produces a shape that
is complementary to the hole (4).

5.

A tension member termination according to one of Claims 1 - 3, characterised in that the
30 holes (4) in the receiving body (3) for receiving the filaments (2), are tapering, e.g.,
conical or stepped, where the filaments (2) are inserted into the end of the hole (4)
having greatest diameter, and that the solidifying substance (5) is poured into the hole
(4) around the filament (2), and thereby produces a shape that is complementary to the
hole (4):

35

6.

A tension member termination according to one of the preceding claims, characterised in that the holes (4) in the receiving member (3) are blind holes.

5 7.

A tension member termination according to one of the preceding claims, characterised in that the filaments (2) are fed through the holes (4) in the receiving member (3) and project from the side opposite to the insertion of the filaments.

10 8.

A tension member termination according to Claim 7, characterised in that the side of the receiving member (3) opposite the insertion side of the filaments (2) has solidifying substance (5) applied thereto.

15 9.

A tension member termination according to one of the preceding claims, characterised in that there is provided a ring member (10), e.g. a conical sheath, which envelopes the tension member at or close to the transition zone to guide the spreading out of the filaments (2).

20

10.

A tension member termination according to one of the preceding claims, characterised in that the receiving member (3) is adapted to be inserted into a recess in a suspension member.

25

11.

A termination of a tension member (1), which tension member (1) comprises a plurality of carbon fibre filaments gathered into one or more strands (2) in which the filaments run against one another, around which strands there is provided a sheath (3), each strand (2) being terminated in a receiving member (6) and the receiving member (6) being suspended in a suspension member (7), wherein the receiving member (6) having an outer dimension reaching beyond the strand (2) over at least a part of the circumference, characterised in that the receiving member (6) having a flange resting on a shoulder on the suspension member (7), and that a recess (12) is formed through the shoulder, the recess having a dimension larger than the diameter of the strand, through which recess the strand is adapted to be lead when coupled to the suspension member (7).

35

12.

A termination of a tension member according to Claim 11, characterised in that the suspension member (7) is equipped with several recesses (12) for receiving a respective receiving member (12).

5

13.

A termination of a tension member according to Claim 12, characterised in that the recesses (12) are arranged in a ring formation on the suspension member (7).

10 14.

A termination of a tension member according to Claim 12 or 13, characterised in that the recesses (12) are arranged in several levels on the suspension member (7).

15.

15 A termination of a tension member (1), which tension member (1) comprises a plurality of carbon fibre filaments gathered into a plurality of strands (2) in which the filaments run against one another, around which strands there is provided a sheath (3), each strand (2) being terminated in a receiving member (6) and the receiving member (6) being suspended in a suspension member (7), characterised in that the receiving members (6)
20 are arranged in several levels on the suspension member (7).

16.

Termination of a tension member according to Claim 15, characterised in that the several levels are placed radially outside of and inside of each other, respectively.

25

17.

Termination of a tension member according to Claim 15 or 16, characterised in that the receiving member (6) having a flange resting on a shoulder on the suspension member (7), and that a recess (12) is formed through the shoulder, the recess having a dimension
30 larger than the diameter of the strand, through which recess the strand is adapted to be lead when coupled to the suspension member (7).

18.

Termination of a tension member according to Claim 17, characterised in that the
35 recesses (12) are arranged in a ring formation on the suspension member (7).

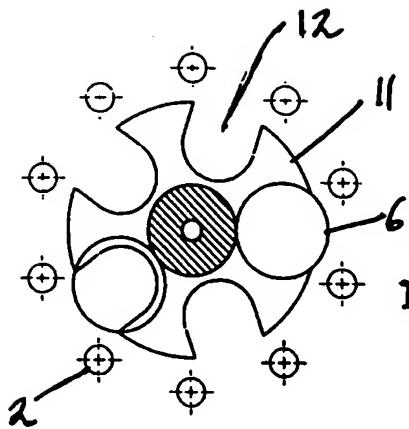


Fig. 2

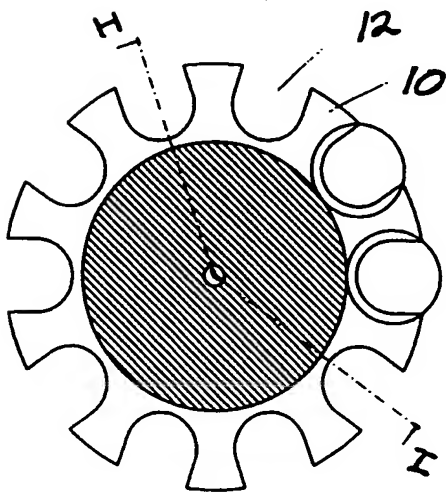


Fig. 3

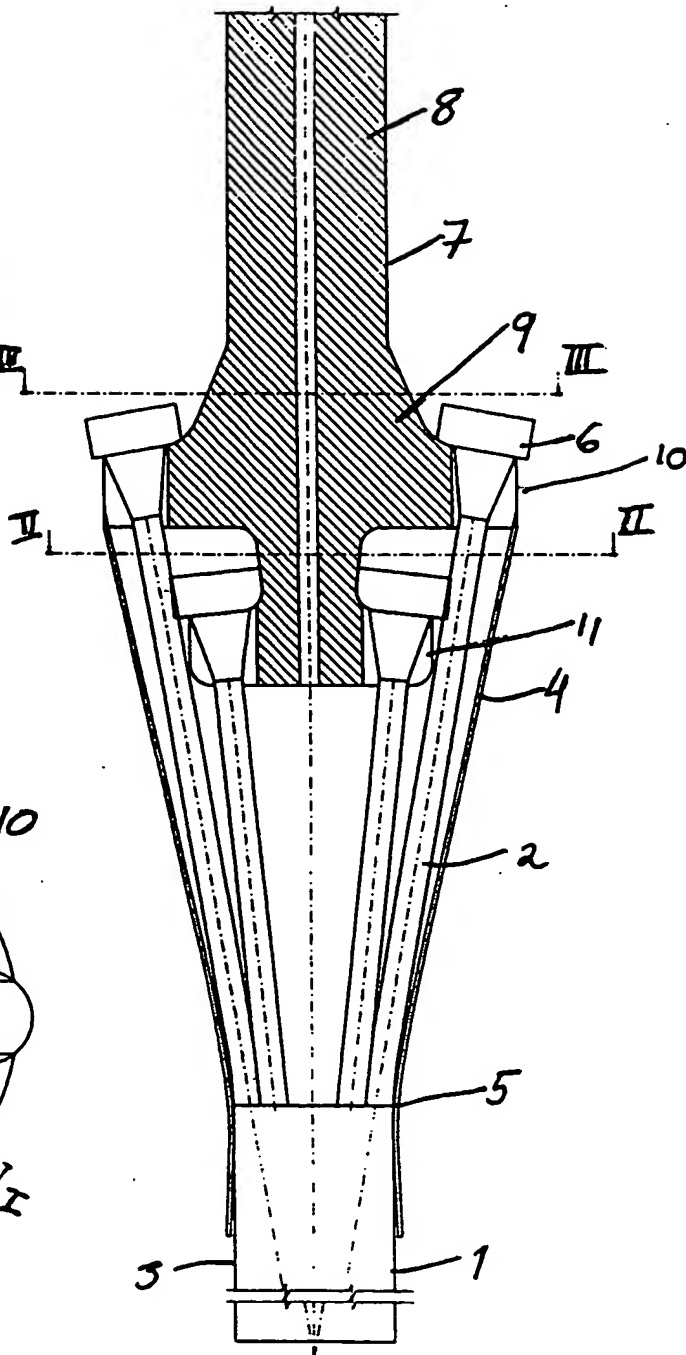


Fig. 1

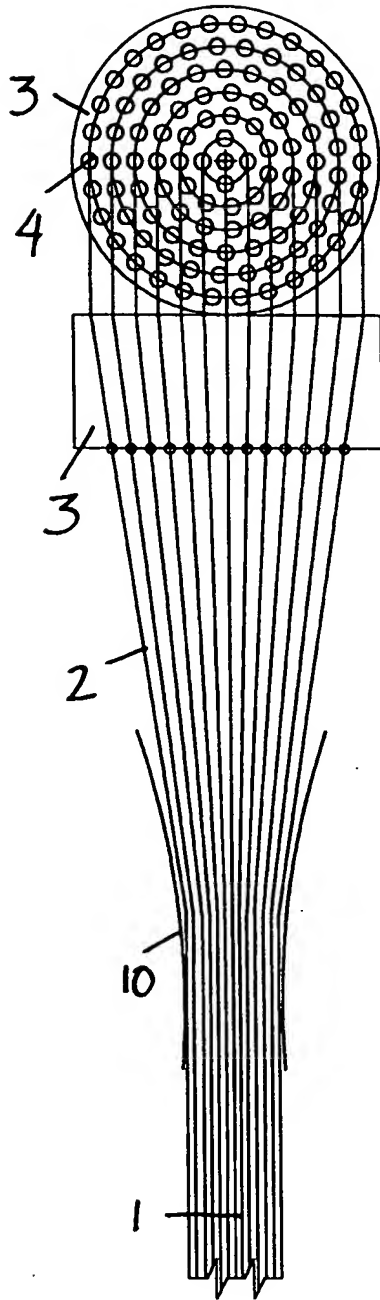


Fig. 4

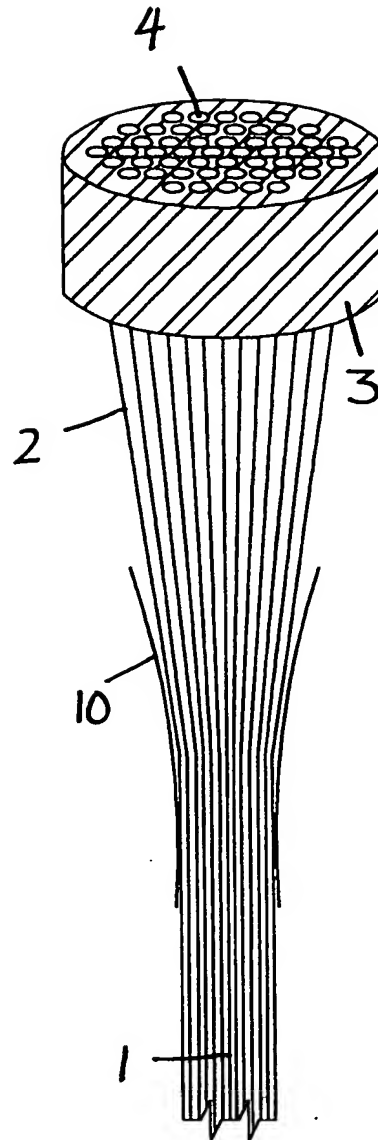
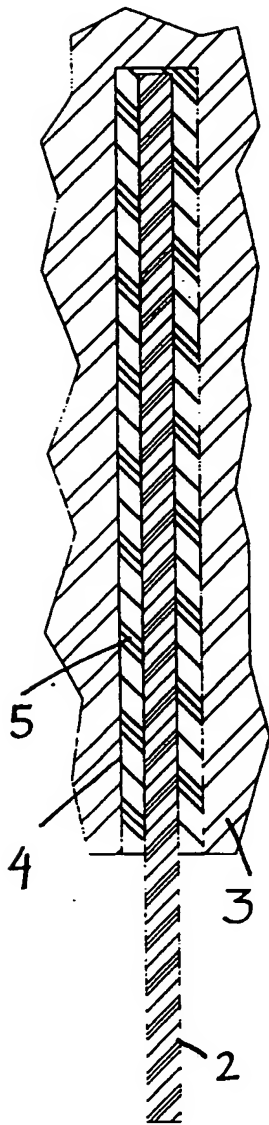
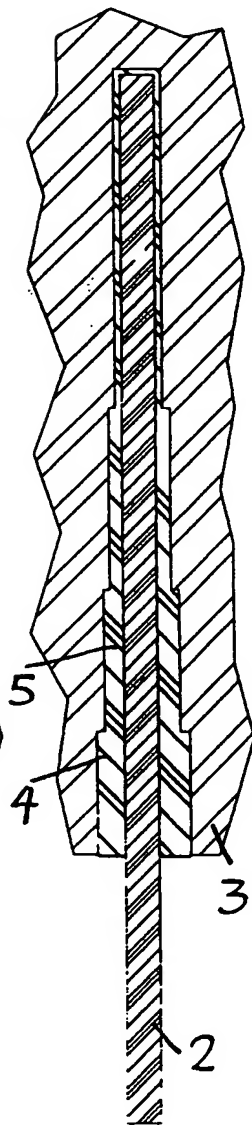
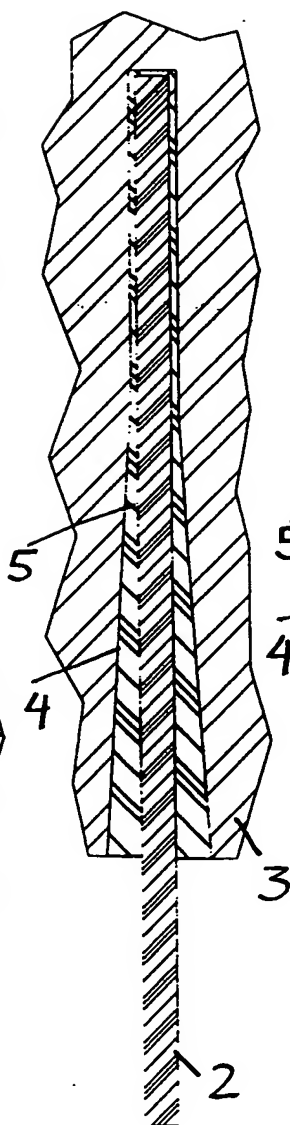
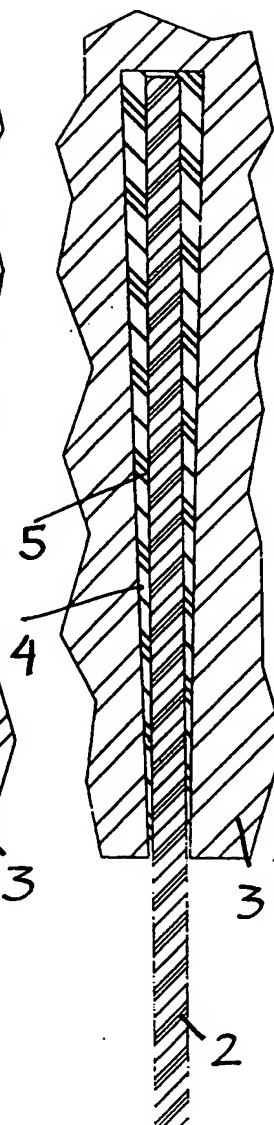


Fig. 5

Fig. 6a**Fig. 6b****Fig. 6c****Fig. 6d**

INTERNATIONAL SEARCH REPORT

International application No.

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C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT		
Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 3866273 A (A. BRANDESTINI ET AL), 18 February 1975 (18.02.75)	1-3,7,8-10
Y		11-18
A		4-6
	--	
X	US 4407770 A (L. RIPOLL), 4 October 1983 (04.10.83), figures 1,2	1-9
Y		11-18
A		10
	--	
Y	US 5611636 A (J.F. FLORY), 18 March 1997 (18.03.97)	11-18
A		1-10
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INTERNATIONAL SEARCH REPORT

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A. CLASSIFICATION OF SUBJECT MATTER

IPC6: E04C 5/12, F16G 11/12

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

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IPC6: F16G, E04C

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C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	DE 2407828 A1 (WESTFÄLISCHE UNION AG), 21 August 1975 (21.08.75), figure 1 --	1,18
Y	GB 1125176 A (P.S.C. EQUIPMENT LIMITED), 28 August 1968 (28.08.68), figures 3,11 --	11-18
A	--	1-10
A	GB 1571327 A (BUREAU BBR LTD.), 16 July 1980 (16.07.80), figures 1-3 --	1-18

☒ Further documents are listed in the continuation of Box C.☒ See patent family annex.

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